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Assessment of new and renewable energy resources potential and identification of barriers to their significant utilization in Pakistan

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Abstract

The paper presents a review of the assessed potential of the renewable resources and practical limitations to their significant use in the context of present scenarios and future projections of the national energy mix for Pakistan. Solar, wind, biomass and micro hydel resources are likely to play an important role in future; however these should be seen as supplementary resources and not as alternatives. IEP approach and consistent policy instruments are needed for sustainable development of RETs.

Keywords: Renewable-potential; Solar-energy; Wind-power; Limitations; Pakistan

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1. Introduction

Pakistan is one of the fast growing economies of the South Asia, which during the fiscal year 2004–2005 showed a real GDP growth rate of 8.4%, and growth in the industrial, agriculture and services sectors as 12.5%, 7.5% and 7.9%, respectively [1]. In the same period, the net energy consumption was recorded around 32 million TOE, which is increasing at a rate of 4.9% [2]. Pakistan enjoys a very important strategic location: bordering the Arabian Sea, between India on the east and Iran and Afghanistan on the west and China in the north, and therefore being expected to serve as an international trade and energy corridor in future.

In order to maintain its economic growth and in order to support the regional and global economic initiatives of the future, Pakistan needs to strengthen its energy security by all means.

The current energy picture of Pakistan is depicted by Figs. 1 and 2.

The industrial and household sectors consume about 61% of the total national energy mix; mainly electricity and natural gas. The transport sector consumes 31.4% of the total national energy mix; about 98% of the transport fuel is provided by oil products. About 80% of the primary energy demand is being met by the natural gas and oil. All of the natural gas needs are being met through indigenous production, however indigenous production of oil is limited to 64,000 bbl/day against a consumption level of 3,51,400 bbl/day [1], due to which a huge share of import bill is taken by oil alone. Except for hydro, no other renewable source has a significant role in the present energy mix of the country; however because of the growing energy needs and the threat of diminishing conventional resources, their future role cannot be ignored.

Table 1 shows the actual primary energy supply data for the years 2000–2005 wherein renewable sources, other than hydro and nuclear have no share. However, in the future supply projections shown in the same table, based on the future plans of the Government of Pakistan, significant share has been assigned to the renewable sources.

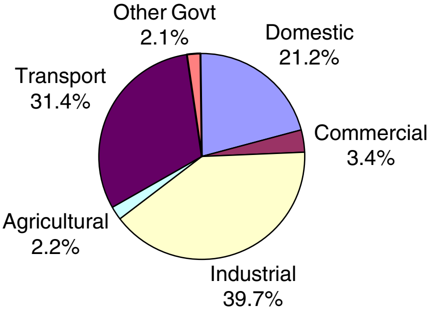


Fig. 1. Sectoral energy demand mix 2005. *Data source*: [2].

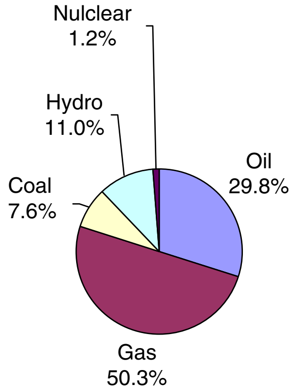


Fig. 2. Primary energy supply mix 2005. *Data source*: [2].

Table 1
Primary energy supply by source (MTOE)

Year	Actual*						Projections**				
	2000	2001	2002	2003	2004	2005	2010	2015	2020	2025	2030
Oil	18.74	19.27	18.39	18.02	15.21	16.33	20.69	32.51	45.47	57.93	66.84
Gas	17.49	18.4	19.25	20.59	25.25	27.95	38.99	52.98	77.85	114.84	162.58
Coal	2.05	2	2.2	2.52	3.3	4.22	7.16	14.45	24.77	38.28	68.65
Hydro	4.6	4.1	4.52	5.34	6.43	6.12	11.03	16.4	21.44	30.5	38.93
Renewables	0	0	0	0	0	0	0.84	1.6	3	5.58	9.2
Nuclear	0.09	0.48	0.55	0.42	0.42	0.67	0.69	2.23	4.81	8.24	15.11
Total	42.97	44.25	44.91	46.89	50.62	55.29	79.4	120.2	177.34	255.37	361.31

Hydro & Nuclear Electricity equivalent converted @ 10,000 BTU/KWh as if generated by fossil fuels.
Data source: *Pakistan Energy Year Book, 2004 & 2005, **MTDP-Government of Pakistan.

The following sections present a review of the assessed/perceived potential and practical limitations of the new and renewable resources in Pakistan; except for the hydro and nuclear; which are generally treated separately.

2. Power generation options

Pakistan is located in tropical region and most parts of the country have moderate winters but very hot summers. Industrial, commercial and household sectors are the major users of electricity and this trend is likely to continue. Without a major technological breakthrough and a revolutionary change in social habits, the use of renewable technologies may not find a significant place in the society in the foreseeable future. Therefore only those renewable sources are likely to play an important role in the national energy mix, which have the potential for power generation based on the proven techno-economic feasibilities.

Table 2 shows the past and present power generation mix data in terms of installed capacity and Fig. 3 presents the percentage share of the primary energy sources in the power generation mix.

Table 2
Installed power generation capacity growth in Pakistan (MW)

Year	Hydel	Thermal				Nuclear	Grand total
		WAPDA	KESC	IPPs	Subtotal thermal		
1960	253	113	56	0	169	0	422
1970	667	656	392	0	1048	0	1715
1980	1567	1118	673	0	1791	137	3495
1990	2897	3512	1318	0	4830	137	7864
2000	4826	5131	1756	5549	12,436	462	17,399
2001	4857	4830	1756	5583	12,169	462	17,488
2002	5041	4735	1756	5795	12,286	462	17,789
2003	5041	4735	1756	5794	12,285	462	17,787
2004	6491	4735	1756	5808	12,299	462	19,252
2005	6494	4835	1756	5832	12,423	462	19,379

Data Sources: Power System Statistcs-29th Issue and Pakistan Energy Year Book, 2005.

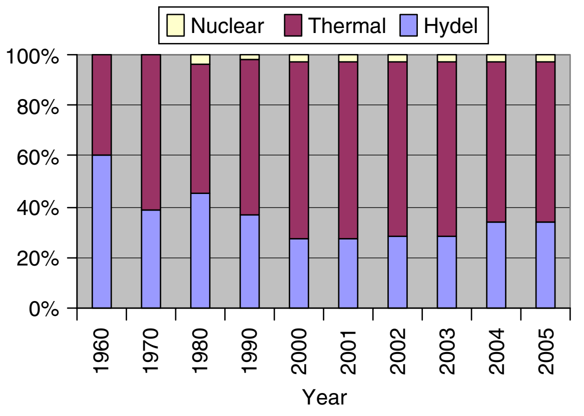


Fig. 3. Power generation mix-Pakistan. *Data source*: [3].

In 2005 the shares of thermal, hydel and nuclear generation were about 64.1%, 33.5% and 2.4%, respectively; while the renewable sources had no worth mentioning share [3]. In the context of this situation the intended targets for next 25 years shown in Table 1 above, particularly those of renewable sources, seem quite over ambitious. A detailed review of the availability perceptions and the barriers to their development is needed.

3. Assessed/perceived potential and limitations

The search and development of alternate energy resources caught the attention of the researchers and the governments all over the world after the oil price shocks of 1970s. Government of Pakistan, with the help of international agencies, also established R&D institutions and offered S&T scholarships in the field of renewable energy during 1980s. Renewable resource potential was assessed and reported by the researchers involved in these programs, some demonstration level projects were also executed; however as it can be observed from the data presented above, no significant use of these resources could be

achieved. As a part of its rigorous drive to ensure national energy security, the government of Pakistan has recently established an institution namely Alternate Energy Development Board; which has started fresh efforts with a dynamic approach and the ambitious targets depicted in Table 1 are mainly based on its future plans. Other institutions, working under the Directorate General of New and Renewable Energy Resources, are also playing significant role. Although multiple new and renewable resources are being considered in Pakistan, but real hopes are attached with the solar and wind resources. The potential and limitations of the renewable resources was discussed earlier by Mukhtar [4] and the following sections of the paper present a fresh review of the individual resources after the lapse of 15 years.

3.1. Solar energy

Because of unique geographical location and favorable climatic conditions most parts of Pakistan receives very high solar radiation intensities. The measured monthly averages of solar radiation for the four provincial capitals of Pakistan, reported by Nasir and Raza [5], are shown in Table 3.

Direct and diffuse radiation intensities, determined through empirical relationships, for 40 locations of Pakistan [6] and the radiation intensity contour map of Pakistan drawn on the basis of satellite APT images [7], have established that almost half of Pakistan has the potential areas for establishing large-scale solar utilities.

Inherent variability of the solar radiation intensity, with time of the day, season and orientation of the receiving surface have also been studied by different researchers and considerable design data is available for customized local design of the solar systems. Raja and Twidell [8] presented statistical relationships of measured global insulation, Iftikhar [9] established a correlation between the monthly mean of sunshine duration and global solar radiation of a location based on the site elevation above sea level and the latitude. Syed et al. [10] presented an inverse Gaussian relationship between the percentage cumulative frequency distribution for average daily insulation and the energy in $MJ/m^2/day$ for Quetta; the highest solar radiation receiving city of the country [11].

The prospects of solar energy utilization in Pakistan have also been extensively studied by the researchers. Sukhera [12] proposed solar energy conversion processes suiting the local conditions of the Cholistan desert area. Hasanain and Gibbs [13] discussed the significance of renewable resources for the development of remote areas in Pakistan.

Table 3
Monthly average

	Solar radiation (kWh/m^2)	
	Minimum	Maximum
Quetta	3.6	7.65
Karachi	3.39	6.31
Peshawar	2.4	6.35
Lahore	2.8	6.27

Source: [5].

Mukhtar [14] analyzed the economic feasibility of solar air conditioning, Lutfi and Vezirogla [15] proposed and analyzed a solar-hydrogen system for Pakistan.

The achievements of the institutional level R&D efforts of Pakistan, in the fields of solar thermal and PV system, up to 1996 were described by Iftikhar et al. [16] and a later outlook was presented by Umar et al. [17]; concluding that the existing infrastructure remained unable to advance the status of solar energy in Pakistan, although a comparative picture of the countries in the region painted by Roy [18] gives an encouraging outlook for Pakistan.

The present status of solar energy technologies, lack of policy instruments to integrate the techno-economic and socio-political behaviors and actions, and inconsistencies of the government policies present the major barriers to the significant utilization of the solar energy.

During the year 2004–2005, the AEDB electrified with solar PV system 601 houses in different villages of the four provinces, while its target is 400 more houses [2].

In the light of above discussion, in spite of the tremendous assessed or perceived potential of solar radiant energy in Pakistan, it is not easy to attach much hope to the solar resource. It is not likely to play any significant role in the national energy supply mix in the foreseeable future. Solar energy must be seen as an important supplementary resource but not as an alternative.

Solar energy technologies development and use is very important and useful for the developing countries like Pakistan provided that the factors of long-term sustainability and economic feasibility are not ignored.

3.2. Wind energy

Wind power potential in Pakistan is moderate, however yet it is the most promising renewable resource for power generation. The monthly average wind speeds for the four provincial capitals of Pakistan, reported by Nasir and Raza [5] is shown in Table 4.

Using the average data from 59 locations of the country, iso-wind speed contours have been drawn by constructing monthly and yearly maps [19], while wind data for 16 locations in the Baloachistan province alone has been analyzed and presented by Nasir et al. [20]. However Iftikhar and Riazuddin [11] argued that the prime sites for wind power installations are the coastal area, arid zone and the hill terrains. Table 5 shows the wind power capacity growth plan of the Government of Pakistan; which is the major basis of including renewable share in the energy mix projections of Table 1.

Table 4
Monthly average

	Wind speeds (m/s)	
	Minimum	Maximum
Quetta	2.5	4.4
Karachi	2.75	6.7
Peshawar	0.6	1.7
Lahore	0.7	1.6

Source: [5].

Table 5

Period	Capacity addition (MW)	Cumulative installed capacity at the end of period (MW)
2005–2010	700	700
2011–2015	800	1500
2016–2020	1500	3000

Source: Pakistan Energy Year Book, 2005.

The current status, reported in [2] indicates that about 100 micro wind turbines have been installed and 467 houses have been electrified so far. Foreign and private investment in the field is being encouraged.

In view of the situation described above, the planned projections seem a little over ambitious, however the wind power still seems to be the best renewable resource that has the potential to supply significant off grid power.

3.3. Biomass

More than 70% of the population in Pakistan lives in the rural areas, where access to commercial energy resources is limited and traditional methods of using wood, animal waste and crop waste for domestic fuel needs are the only choice. Efficiencies of use are very low and most of the potential is wasted because of non-scientific conventional technologies. Muhammad [21] has portrayed the energy supply situation in the rural areas of Pakistan, while Bhattacharya et al. [22] have estimated the biomass saving potential for seven Asian countries; including Pakistan.

Pakistan Council for Renewable Energy Technologies have reportedly installed 1500 family size biogas plants, 3 community size biogas plants and one $1000\,m^3$ thermophillic unit [2]; however the past experience shows that such plants failed to contribute for longer time. The argument is supported by the fact that hardly any biogas plant installed 15–20 years ago under similar government funded project is presently operating.

In the light of above discussion, it is suggested that instead of focusing on the small scale family and community units, the huge assessed potential of biomass should be utilized to develop large-scale biogas plants operating on crop and animal wastes in the rural areas and on street waste in the urban areas. Experience from the success of such large-scale biogas pilot projects in Japan can help the planners in this regard.

3.4. Other renewable sources

Potential for renewable sources, other than those described above, have also been indicated through various studies; however significant use promise is only provided by the micro hydel power plants. 300 MHP plants ranging 5–50 kW have been installed in the hilly terrain of NWFP [2] and considerable potential has been indicated by the thousands of streams running down from the northern mountains. Considerable potential is also indicated by the huge canal network of the national irrigation system; for which a demonstration project (3 kW unit) on a small canal at Taxila has recently shown prominent success.

Feasibility of using bagasse (sugar cane waste) as fuel in Turkey and Pakistan has been reported by Kilicaslan et al. [23], while a number of sugar mills in Pakistan have started using bagasse for CHP applications. Prospects for obtaining Bio fuels from the popular crops have also been established through a number of demonstration projects [2]. Prospective geothermal areas in Pakistan have been identified by Tauqir [24] but no significant effort is on record for harnessing geothermal energy. R&D projects of developing fuel cell technology, utilizing ocean tidal potential, and revisiting muscular power are also in progress at the level of individual researchers or institutions but no organized efforts are on record.

4. Conclusions

It is concluded from the above discussion that although the renewable resources can not serve as alternative of conventional energy resources, yet these may serve to supplement the long-term energy needs of Pakistan to a significant level. However tremendous resource potential, assessed or perceived alone can not guarantee the harnessing of these resources to a significant utilization level. An integrated energy planning approach, consistency in government policies and rational policy instruments to deal with the techno-economic and socio-political barriers are the pre-requisites for long-term sustainable development of the RETs.

Both over emphasizing and under rating the renewable resource potential based on departmental level objectives are needed to be avoided and the real issues for RETs development and significant use are needed to be recognized and addressed at policy level. The policy options based on the real issues of RETs development for four mountain communities, including Pakistan, have been described in detail by Kamal [25] and were earlier outlined to some extent for Pakistan by Mukhtar [4].

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